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Jensen, Jørgen Juncher; Andersen, Ingrid Marie Vincent; Nielsen, Ulrik Dam; Andersen, Poul

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Theme: Innovative approaches to learning and teaching, scholarship and research now and into the future.

The New Maritime Engineering Education at the Technical University of Denmark (DTU)

Jørgen Juncher Jensen

Professor, DTU (jjj@mek.dtu.dk)

Ingrid Marie Vincent Andersen

Head of Centre, DTU Maritime (imva@mek.dtu.dk)

Ulrik Dam Nielsen

Associated Professor, DTU (udn@mek.dtu.dk)

Poul Andersen

Associate Professor, DTU (pa@mek.dtu.dk)

Mailing address: Dept. Mechanical Engineering, Technical University of Denmark, DK 2800, Kgs. Lyngby, Denmark

Abstract Until 2010, the maritime engineering education at the Technical University of Denmark (DTU) followed the rather classical naval architecture approach with the main focus on marine hydrodynamics and strength of ship structures. The number of students was rather modest and constant. However, at that time the last major ship yard in Denmark was closing down and ship operation, together with ship design, became the main working area for the students after graduation. It was then decided to broaden the naval architecture education to a maritime engineering education taking marine logistics, management, transport optimization and engine system design into to the curriculum. Furthermore, the concept of green shipping was introduced wherever relevant in teaching modules at DTU and two new maritime engineering courses were introduced: (1) Sailing practice in a merchant vessel or DTU's research vessel (guided by the experience gained from Australian Maritime College in a similar course) and, (2) Green transportation dealing holistically with global ship transport. Furthermore, study trips to Asia visiting ship yards have been made possible by support from the various private funds.

This new maritime engineering education has so far been very successful with the number of students increased by a factor of two and with very good job opportunities in the Danish maritime industry. A spin-off of this change is DTU's participation in a dual MSc degree engineering program: Nordic Master in Maritime Engineering where DTU is responsible for the study track Ship Operations. This change has also led to the creation of the centre Maritime DTU as a one-point entry for the industry and maritime authorities regarding R&D related maritime issues.

The paper will discuss the process and the way ahead for further strengthening the interaction between maritime industries, ship owners, maritime authorities and universities dealing with maritime engineering in Denmark and internationally.

Keywords: Maritime engineering education, engineering curricula, globalization, green shipping, holistic education

1. Background

The significant changes in the maritime industry in Denmark and the EU within the last couple of decades have of course also had implications for the maritime engineering education. Whereas ship design and ship building at numerous shipyards in Denmark defined the core topics in the education in the nineties, the shift towards focus on ship operation and ship management has led to significant changes in the education. The first major step was taken after an internal seminar (Innovation in the Maritime Industry) in Denmark in May 2011 and a subsequent survey report, [1] (in Danish), for a pointing out recommendations for a modified maritime engineering education. The most profound change was to abandon the old definition of a *naval architect* as one being solely able to do stability, propulsion, sea keeping and strength of ship structures and replace him/her by a *maritime engineer* with a more holistic background covering topics like ship management, ship route optimization, ship logistic, ship economy in addition to the classical disciplines. Of course, all of these topics cannot be covered in depth in the education and that led to a so-called T-shaped competence profile, [2], where the horizontal bar represents a broad coverage of many relevant disciplines for the maritime industry and the vertical bar the actual maritime specialization chosen by the student. The introduction of this T-shaped education has been relatively smooth so far at the Technical University of Denmark (DTU) in the BEng and BSc education as described by Andersen and Nielsen [2] partly due to the willingness of lecturers in non-maritime courses to include wherever relevant maritime related examples and course work and partly due to the commitment of the maritime industry to give guest lectures, define relevant cases for project work and offer student jobs. The success can be measured in the number of undergraduate students with a maritime profile and this number has been doubled in the last year, raised from about 30 to 60. As the intake of new students at DTU is constant, this increase was more than expected.

The next step is to ensure that the increased interest by the students in the maritime field is kept. The focus will mostly be on:

- Increased on-hands experience with ship operation by sailing practice in merchant vessels or in the research vessel owned by DTU
- Dedicated projects with the maritime industry with focus on green technologies
- New courses on the MSc level dealing with current topics of interest by the industry (e.g. energy efficient ships, sustainability, retrofit, decision support, exhaust gas emission, arctic ship operation and use of composite materials)
- Help to prepare individual study plans for maritime students to ensure proper course selections for both the horizontal and vertical bar in the T-shaped education profile taking into account the main interest of the student. This is no trivial job given that DTU offers around 1,000 courses on a yearly basis
- Cooperation with other Nordic universities through the Nordic Master in Maritime Engineering to increase the specialization available for the students
- Study trips for the students to ship yards in the Far East

In the following sections some of the bullet points above will be addressed.

An important instrument in this effort will be the newly established centre: Maritime DTU. The centre is virtual in the sense that it covers all maritime related activities at DTU without moving people from their current research groups and departments. The centre shall act as a one-point entry to DTU for the maritime industry, the students and the researchers for information and shared knowledge about education, problems, possibilities and solutions of current interest for the maritime sector. Here the students can get advice on course selections and help to prepare their study plan. One of the instruments in the centre will be a website open for everyone

from high school students to the industry. In the centre, maritime related information of new courses, guest lectures, project proposals, internship, student job, social events etc. will be made available. The website will also link to the maritime students' own website, [3], as this organisation, Nul-Kryds, is very active in the social life at the campus for students with maritime interests and also arrange company visits, study trips and information evenings.

2. On-hands Experience with Ship Operation by Maritime Engineering at Sea

One of the main recommendations from the survey in 2011 was that it would be beneficial to both students and the industry if the students get practical experience working on a marine structure in operation during their study. For offshore structures it is difficult, due to the strict safety requirements, but for sailing on board merchant vessels the situation is better. Previously, students have occasionally been going to sea for a short period typically during the summer vacation, but now a specific BEng/BSc course has been formulated:

41280 Maritime Engineering at Sea, 5 ETCS

The duration of the course is approximately three weeks and the actual time of the year depends on the sailing schedule of the chosen vessel. The core content is to give the students hands-on-experience in the operation of a large vessel and the possibility to relate theoretical predictions to actual measurements. The complete list of learning objectives of the course is given below and, although not all of the objectives necessarily are fulfilled during a specific execution, a student who has met the objectives of the course will be able to:

- consider the ship from a holistic point of view
- explain the overall problems designing a ship
- work in teams with people with different background
- explain the role of the crew members
- explain the overall flow in the energy systems on-board
- explain the role and function of the different components in the energy system
- calculate the exhaust emissions from the ship
- measure and estimate the noise and vibration level on-board the vessel
- measure the ship motions in waves
- evaluate the route chosen in relation to the weather encountered
- estimate a proper trim of the vessel in the given loading condition
- estimate the wave loads on the ship

Two options of the course exist:

Option 1 (A merchant vessel): Approximately 3 weeks on board a Danish merchant vessel. Max. 2 students on each trip.

Option 2 (DANA): 5-7 days on board DTU's research vessel DANA. 2-10 students on each trip.

In the first half of 2014, 13 students have signed up for option 1 and 6 students (maximum number this year) for option 2. In option 1, the ships have been or will be container vessels from Maersk Line and tankers from Maersk Tankers, but other options are also available and were used last year, e.g. DFDS and Royal Arctic Line. On board the vessels the specific topics have been inspections of ballast tanks, measurements to be used in connection with retrofit of a new bulbous bow, retrofit of lightning system, and noise measurements, to mention a few. Due to a generous funding from the Danish Maritime Fund and the hospitality of the ships and ship owners, the sailing practice takes place worldwide with port calls in China, Japan, Singapore, US, Brazil etc. without travelling expenses for the students themselves. This obviously adds to the incentives and possibilities for the students to take the course.

Option 2 is available only if DTU's marine research vessel DANA is going for a longer trip. This was the case in March 2014 where the ship was headed from Denmark to Bermuda for a marine biology study of the European eel. Six maritime engineering students could join the trip and they had a good (and due to the weather also rather tough) journey from February 28 to March 14. During the trip, when seasickness allowed for it, noise and vibration measurements were conducted with professional equipment (SVAN 959) sponsored by the Danish Maritime Fund. In addition various jobs were undertaken like new stability calculations for the vessel together with a recording of the daily operations of the vessel in harsh weather (Figure 1). Basically, the student activities on board followed the same approach as described by Thomas et al. [4] for student activities at sea at the Australian Maritime College.



Figure 1 Student experience on board the research vessel DANA in harsh weather

3. Dedicated Projects with Industry with Focus on Green Technologies

The Danish maritime industry has taken up the recommendations from the survey report very seriously and the industry has been much more visible at the university the last couple of years. Companies are very positive as regard students going to sea as described above, but also in providing guest lectures to courses, student jobs and offer interesting proposals for BEng, BSc and MSc projects. The project proposals cover all aspects from the maritime field and come from ship consultancies, ship owners, offshore oil drilling companies, engine manufacturers, marine equipment suppliers and the Danish Maritime Administration. Currently, about 35 proposals can be found on the DTU website, but continuously new proposals arrive at DTU Maritime, where the projects are scrutinized and modified such that they satisfy the university requirements for project work. These project proposals deal primarily with energy efficiency, safety and environmental issues, but logistics, life cycle cost and operational management are also part of many of the proposals. Often they contain an innovative design aspect as, e.g., in new vessels for installation and/or maintenance offshore wind turbine

parks. All this fits nicely into the new holistic maritime engineering education, the T-shaped profile, and the students thereby already in their study see applications and the need of the broader education profile.

4. Courses on the MSc Level

The dedicated MSc courses in maritime engineering are limited to four by the university as a part of the desire to limit the overall number of courses offered. The four courses, all taught in English, are:

41216 Structural Assessment of Ships, 5 ETCS: The main emphasis is on the determination of the global response of a given ship sailing in waves. Safety against global failure of the hull girder will be evaluated under normal operation conditions. Accidental loads (collision and grounding) will also be covered as well as rational rule development.

41221 Ship Propulsion and Manoeuvring, 10 ETCS: To provide students with the necessary theoretical background for applying modern scientific methods for analyses of flows with lift, free surface and cavitation, i.e. flows over ships, rudders and propellers. The students will be able carry out hydrodynamic analyses and optimization of propulsion and manoeuvring of ships.

41222 Wave Loads on Ships and Offshore Structures, 5 ETCS: After completing this course, the student should be able to use linear potential flow theory to predict the wave induced motions of floating maritime structures. An understanding of the strengths and weaknesses of different numerical solution techniques will allow the student to make the appropriate choice depending on the application. The primary focus for example applications is on ships, offshore wind turbines and wave power devices.

41275 Ship Operation, 5 ETCS: The overall aim of the course is to provide an understanding of the engineering and mathematical analyses that form the basics of monitoring and decision support systems used for on board/navigational guidance of ships. These techniques are used by naval architects and engineers in the technical departments of ship owners, in classification societies and ship consultancies. Moreover, the student will be trained in advanced methods to evaluate ship operations with regards to the increased focus on energy consumption by and emissions from ships.

All four courses have been modified to accommodate the recent change towards a more holistic maritime engineering education but not as much as the BEng and BSc courses, see [2]. The reason is that the vertical bar, the specializations, in the T-shaped engineer basically consists of methods learned in MSc courses. However, changes have been made regarding the course work examples, and a greater use of guest lecturers and industrial visits. This is especially so in the course Ship Operations where three assignments: Risk of Cargo Loss in a Container Vessel, Analysis of Full-Scale Measurements and, Route Optimization of a Container Vessel reflect the overall changes towards an integrated approach involving mechanical, logistical and management tools. Detailed information of all the courses can be found on web page for DTU, [5].

The prerequisites for the students for these MSc courses are knowledge of the general arrangement of ships and offshore structures as e.g. learn in the BEng/BSc course 41271 Ship Design (10 ETCS). This course was developed some 15 years ago, [6], in close cooperation with experienced naval architects from the Danish maritime industry and the textbook made summarizes the experiences from a vast number of actual ship designs. The textbook is currently under revision to include the rapid change in ship types and ship sizes as well as with a larger focus on energy efficiency and environmental problems.

In addition to the annually running of four MSc courses mentioned above usually 1-2 additional and optional MSc courses are offered each year within a maritime topic of strong current interest. For instance, in 2013 two courses were given on Arctic maritime operations by Professor Pentti Kujala from Aalto University in Finland with a large number of students and participants from the maritime industry.

5. Nordic Master in Maritime Engineering

With the limited number of maritime MSc courses and the associated small staff, not only in Denmark but also in other Nordic countries, it was found appropriate to investigate whether some of the universities could join forces in a common MSc program. It was not an easy task mainly due to different administrative procedures and semester structure. However, a two-year dual degree program Nordic Master in Maritime Engineering was finally established in 2011 between the five Nordic Universities: DTU in Denmark, Aalto in Finland, KTH and Chalmers in Sweden and NTNU in Norway with the following agenda, see [7]:

The Nordic Master in Maritime Engineering is based on the expertise of the participating universities within naval architecture, offshore engineering and maritime engineering. The programme targets international students wishing to profit from the Nordic Five Tech universities' long standing tradition and competence in the field and Nordic students wishing to specialize in a specific area of expertise offered within the alliance.

The education is based on first principles within design, construction and operation of ship and offshore structures, including hydrostatics and stability, hydrodynamics, wave and wind loads and structural analyses. The teaching comprises lectures, assignments, workshops and project work. Theory is supported by experimental work and computer simulations are used intensively.

The students enrolled in the program will spend the first year in one of the countries and the second year in another of these countries. The choice of university depends on the interest of the students, and to facilitate their decisions five study tracks have been formulated: Ocean structures (NTNU), Passenger ships (Aalto), Ship design (Chalmers), Ship operations (DTU) and, Small craft (KTH), with the leading university in each track in parentheses. Admission to the study requires a BSc or BEng including a strong knowledge of mathematics and applied mechanics. The prerequisites within naval architecture depend on the university chosen for the first year. More information on the Nordic Master in Maritime Engineering program can be found on [7].

The program has had a good start with about 30 international students applying each year, but would like to see more Nordic students engaged in the program. So far most of the students come from Asia and the EU.

6. Study Trips for Students to Ship Yards

Sailing practice as described earlier gives the students a very good feeling of what a ship is and how it is operated. However, many students will in their professional life be involved in design of ships or other marine structures and hence some practical experience with actual production of these huge and complex structures will be beneficial. Such a practical experience can hardly be gained in Denmark, nor in the EU as most of these structures today are built in Asia. Therefore a study trip of one week's duration each fall for mainly MSc students was found to be a perfect opportunity, if a financial solution to the travelling expenses could be found. In 2013 four private funds provided a very generous support to a visit to Singapore for 26 students. The outcome of the study trip was rated very high by the students, who visited Keppel FELS yard (Jack-up rig for Maersk Drilling) as well as harbour terminals and design offices. In 2014, a similar study trip is being organised to Korea, visiting mostly ship yards.

In addition to these study trips, also shorter visits to maritime companies closer to Denmark are organized. DNV-GL in Høvik in Norway has been the host several years for annual one-day visits where the students have learned about the various tasks performed by a classification society, including the research and development needed in order to update the rules and regulations.

7. Conclusion

The paper has outlined recent changes in the maritime engineering education DTU initiated by a very fruitful discussion in 2011 between the Danish maritime industry and academia. It has so far been a very prosperous journey from the classical naval architecture education to a more holistic maritime engineering education with a continuous and strong support both from the industry and the university. Not only more students now choose the maritime engineering track but also internally at DTU maritime engineering has become more in focus with the establishment of Maritime DTU, a virtual centre to encompass all maritime engineering activities at DTU.

The feedback from the students has been very positive especially as regard the hand-on experience at sea. This is clearly an important, but also expensive new element in the education and in the future more specific tasks on-board the vessels might be needed in order to improve the immediate gain for ship owners taking students on-board for 2-4 weeks.

Other maritime engineering institutions have of course been looking in the same directions as we have done for strengthening the visibility and attraction of the education among engineering students. A good example is the *Proceedings of the International Conference on Education and Professional Development of Engineers in the Maritime Industry* in which [4] is found. However, most of the important information available for us have been received by personal communication at conferences and meetings.

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